§2. Design Studies on Long-life Breeder Blanket for LHD-type Reactors

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In case of a liquid blanket, since the breeder liquid can be continuously circulated and refreshed during the reactor operation, the blanket lifetime is essentially limited by the total displacement damage and He production in structural materials under irradiation by fusion neutrons. There are many candidates for structural materials such as reduced activation ferritic steel (RAFS), vanadium alloy, and SiC/SiC composite. In case of RAFS, which has a very mature material database and is chemically compatible with Flibe even at the outlet temperature of about 830K, the design limit is about 15MWa/m^2 of 14MeV D-T fusion neutron irradiations, which is equivalent to about 120 dpa of neutron damage. This means that the lifetime is 10 years under 1.5MW/m^2 as adopted so far in FFHR designs, and replacement of blanket units is needed three times in the reactor life of 30 years. Therefore, if the effective wall loading could be reduced by a factor of 3, then no replacement would be required.

This concept was proposed about 30 years ago as ISSEC (Internal Spectral Shifter and Energy Converter) by employing thick carbon shields as armor tiles on the blanket wall. In this concept, therefore, the breeder blanket radioactive waste is largely reduced, while the carbon armors, low-level waste with no g-ray, have to be replaced due to neutron damage. In that ISSEC study,

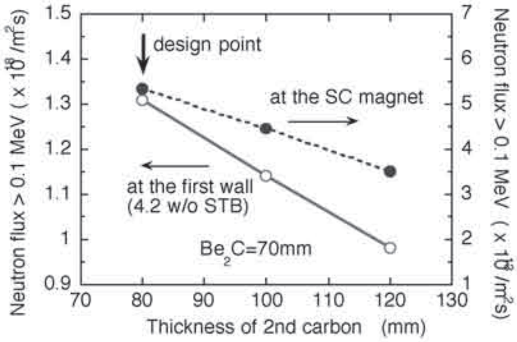

Fig.2. Fast neutron flux at the first wall and the SC magnet.

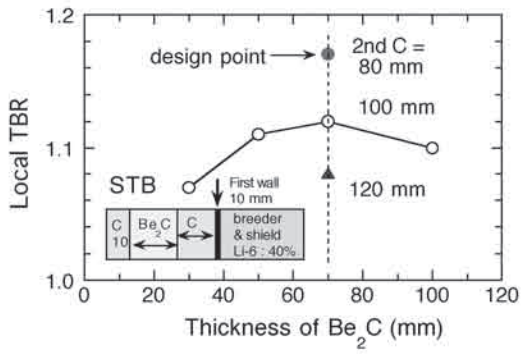

Fig.3. Local TBR vs. the thickness of Be_2C zone.

however, the TBR was below 1.05 even with the Be neutron multiplier in C and 90% enriched liquid Li, and there was no practical means for actively cooling the carbon tiles below about 2000°C to avoid high carbon vapor pressure.

Figure 1 shows the new proposal of STB (Spectral-shifter and Tritium breeder Blanket), where the thickness of Be_2C layer in C and the flibe zone are optimized by MCNP-4C calculations using JENDL3.2 nuclear data. The fast neutron flux (> 0.1MeV) at the first wall of JLF-1 (RAF) is reduced to 1/3 of the original flux (Fig.2). The local TBR over 1.2 is obtained, and the fast neutron fluence to SC magnets is one order reduced to $5x10^{22}$n/m^2, which is sufficient to keep Tc/Tc_0 >0.9 for Nb_3Sn, for instance.

Thermal analyses using ANSYS shows the surface temperature of the carbon armor is about 1600°C under conditions of nuclear heating. Replacement of carbon tiles are needed every few due to neutron irradiations.

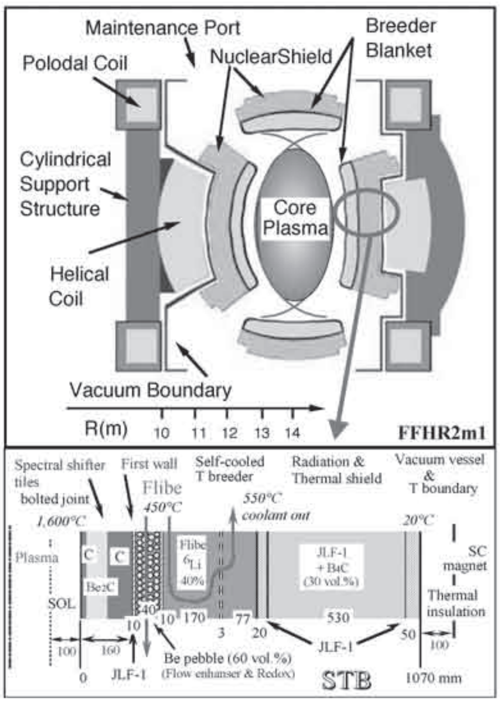

Fig.1. Spectral-shifter and Tritium breeder Blanket (STB) in FFHR2m1.

References:

A. Sagara et al., Fusion Science and Technology, Vol.47 (2005) pp.524-529.
A. Sagara et al., Nuclear Fusion 45 (2005) 258-263.